S I M

Space Interferometry Mission

SIM Science Working Group

SIM System Testbeds (STB-1,3)

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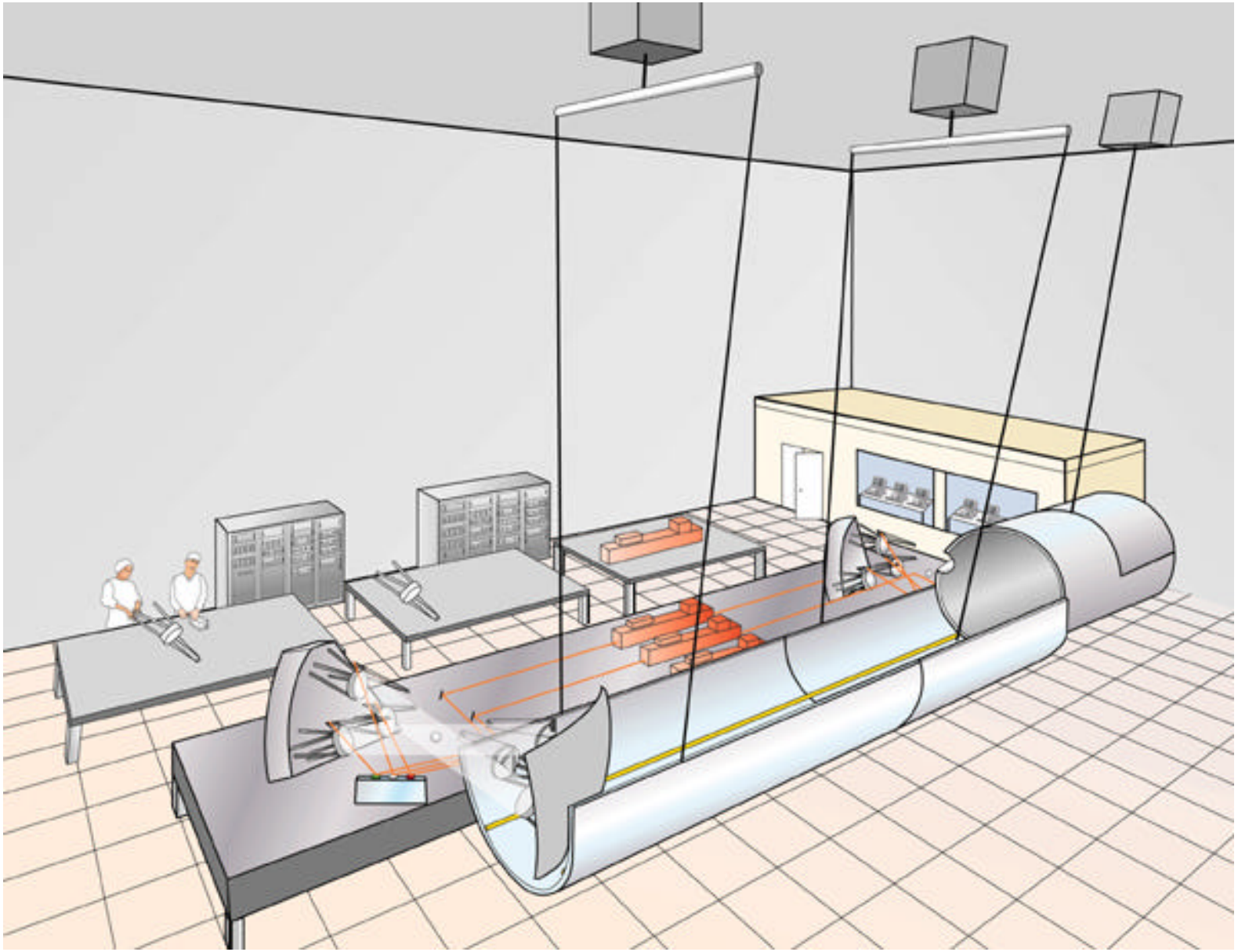
STB-3 Objectives

- Technology Risk Reduction Objectives (TRV Matrix Derived)
  - Demonstrate Interferometer Full Complexity Functionality
    - > 3 Baseline Interferometer
  - Demonstrate System Level Vibration Attenuation
    - > Guide Interferometer Stabilization
    - > Science Interferometer Stabilization -- Angle and Pathlength Feedforward
    - > Interferometer Stabilization for Nulling
  - Validate Integrated Modeling Methodology & Tools
  - "Pathfind" Instrument Integration & Test Approach
- Project Support Objectives
  - Test Interferometer On-board Data Handling
  - Test Interferometer Ground Data System
  - Trouble Shooting During Mission Operations
- STB-3 Will Not:
  - Do Picometer Metrology Demonstration
  - Do Thermo-Mechanical Performance Testing
  - Do Deployments

STB-3 Test Suite -- Top Level

Required Tests	Flight Value	Testbed Value	Notes
Functional Tests			
- Autonomous Alignment	Full-up	Same	
- Interferometer Calibration	Full-up	Partial	
- Interferometer Diagnostics	Full-up	Partial	
- ACS Slew & Settle	4π, TBD settle time	1^{o}, TBD settle time	Limited motion
- Guide Star Acq, Track, & ReAcq	2 stars per tile	2 star positions	Guidestars fixed
- Science Star Acq, Track & Re Acq	15 stars per tile	Same	
- Hexapod Slew & Settle	+/- 7.5^{o}, TBD settle time	Same	
- Collector Pod Slew & Settle	Continuous steps	Same	To Be Reviewed
- Maintain Met Lock During Slews	All slews	Same	
- Maintain Guide Lock During Slews	All slews (TBR)	Same	
- On-board Data Handling	Full-up	Partial	
- Ground Data System	Full-up	Partial	
Performance Tests			
- Guide Star Fringe Acquisition	80 nm	80 nm	
- Guide Star Angle Acquisition	1 arcsec	1 arcsec	
- Guide Star Fringe Tracking	10 nm	10 nm	
- Guide Star Angle Tracking	30 mas	30 mas	
- Science Star Fringe Tracking	10 nm	10 nm	Partial spectrum
- Science Star Angle Tracking	30 mas	30 mas	Partial spectrum
- Science Star Fringe Acquisition	25 um	25 um	
- Science Star Angle Acquisition	3 arcsec	3 arcsec	
- Interferometer Nulling Stabilization	1 nm, TBD mas	1 nm, TBD mas	Partial spectrum

Testbed Cartoon



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Test Article

- Hardback Structure
- Combiner Pod
- 2 Collector Pods
- Fixed Delay Compensator
- Realtime Interferometer Control Software
- Realtime Interferometer Control Electronics

STB-3 Test Article -- Top Level Requirements

Assembly	Requirement	Notes
Hardback Structure		
- Spacecraft	Mass simulator, disturbance source (shaker)	RW's TBD
- Interferometer Structure	HiFi dynamically, no deployments	Material open
	Cable & blanket emulators	
Combiner Pod		
- Beam Combiners	Flight-like (incl detectors & det packaging, not elex)	No nulling BC
- Delay Lines	Flight-like	
- Metrology Source	Good enough for 100's pm metrology	
- Alignment & Fold Mirrors	Flight-like	TBR
- Structure	HiFi dynamically, cable & blanket emulators	Material open
Collector Pods		
- Compressors	Full size primary not required, output beam full size	Correct mass
	Optical qualityTBD waves rms (worse than flight)	
- Hexapods	Flight-like (struts may not have flight lube / seals)	
- Fiducial	Flight-like mechanically, sensors, beacon	
	Optical good enough for 100's pm metrology	
- Acquisition Camera	Off-the-shelf	Correct Mass
- Steering Mirrors	Flight-like	TBR
- Structure	HiFi Dynamically, cable & blanket emulators	
Realtime Control Software		
- Astrometry Tile Ops	Full-up functionality	
- Auto Alignment	Full-up functionality	
- Calibration, Imaging, Diagnostic Ops	Partial functionality	
Realtime Control Electronics	Not Flight-like	Off-board
Fixed Delay Compensator	HiFi Dynamically	

Test Environment

- Facility
- Suspension System
- Pseudo Star
- Support Equipment Electronics
- SE Equipment Software
- Support Structure & Scaffolding

STB-3 Test Environment -- Top Level Requirements

Unit	Requirement	Notes
Facility		
- Seismic Background	Better than MPI	MPI at 5 nm
- Acoustic Noise	Better than MPI	MPI at 5 nm
- Highbay Height	Greater than 6 meters	TA suspension frequency
- Air Handling	Controllable	Can be turned off
- Temperature, Humidity	20C - 25C, 40% - 50%	TBR
- Cleanliness	Class 100,000	Capable of class 10,000
- Highbay Floor Space	3000 sq ft - 4000 sq ft	
- Environmental Monitoring	Continuous	Including disturbances
Test Article Suspension System		
- Natural Frequency	Lower than 0.2 Hz	Separation from TA modes
- Positioning Accuracy	Less than 100 um, 2 arcsec	wrt lab frame
Pseudo Star		
- Number of stars	3	
- Type	Inverse interferometer	
- Waveband	0.4 um - 1.0 um	
- Differential Accuarcy - pathlength	Less than 300 pm	Atmostphere limited
- Differential Accuracy - tip / tilt	Less than2 arcsec	Decouple P / L & tip / tilt
- Differential Stability - tip / tilt	Less than 10 mas	Atmosphere limited
- Positioning Accuracy	Less than 100 um, 2 arcsec	wrt lab frame
- Structure	Rigid as possible	Probably granite table
- Suspension	Soft as possible	Must maintain positioning
Support Equipment Electronics	TBD	
Support Equipment Software	TBD	
Support Equipment Scaffolding	TBD	

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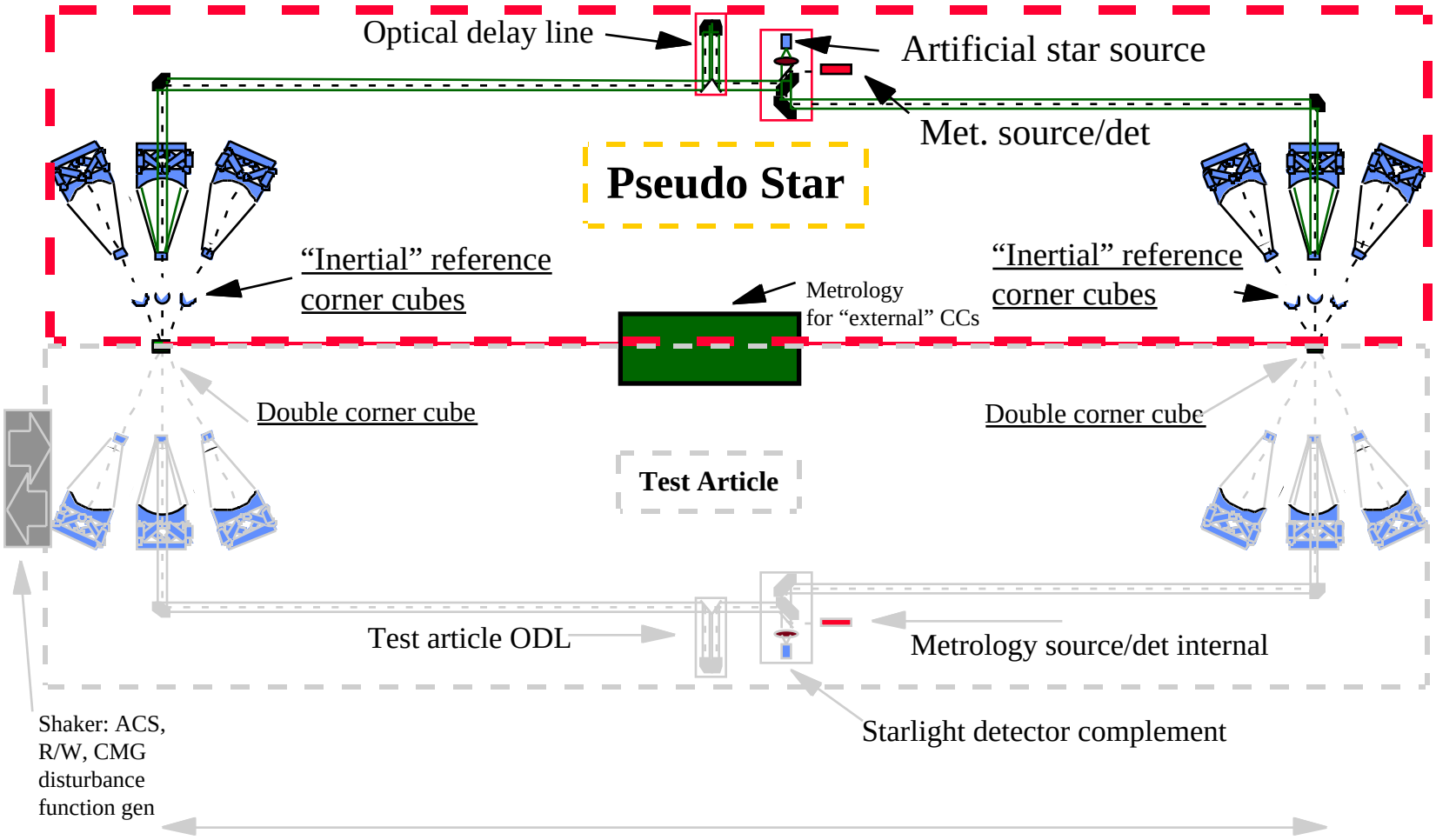
Space Interferometry Mission

STB-3 Pseudo Star

- Supply a “stellar” reference to test the STB-3 test article
  - support all functional testing
  - support performance testing to limits of environment
- Current concept favors the inverse interferometer approach
  - MAM is exploring the point source version of the pseudo star
  - inverse interferometer looks most favorable for testing SIM flight instrument
- Pursuing inertially stabilized approach
  - stars mounted on a rigid, massive table
  - table maximally isolated from seismic and acoustic noise
  - stellar wavefronts tied to inertial space
    - > inertial sensing and optical feedback control
  - pseudo star independent of test article optically and mechanically

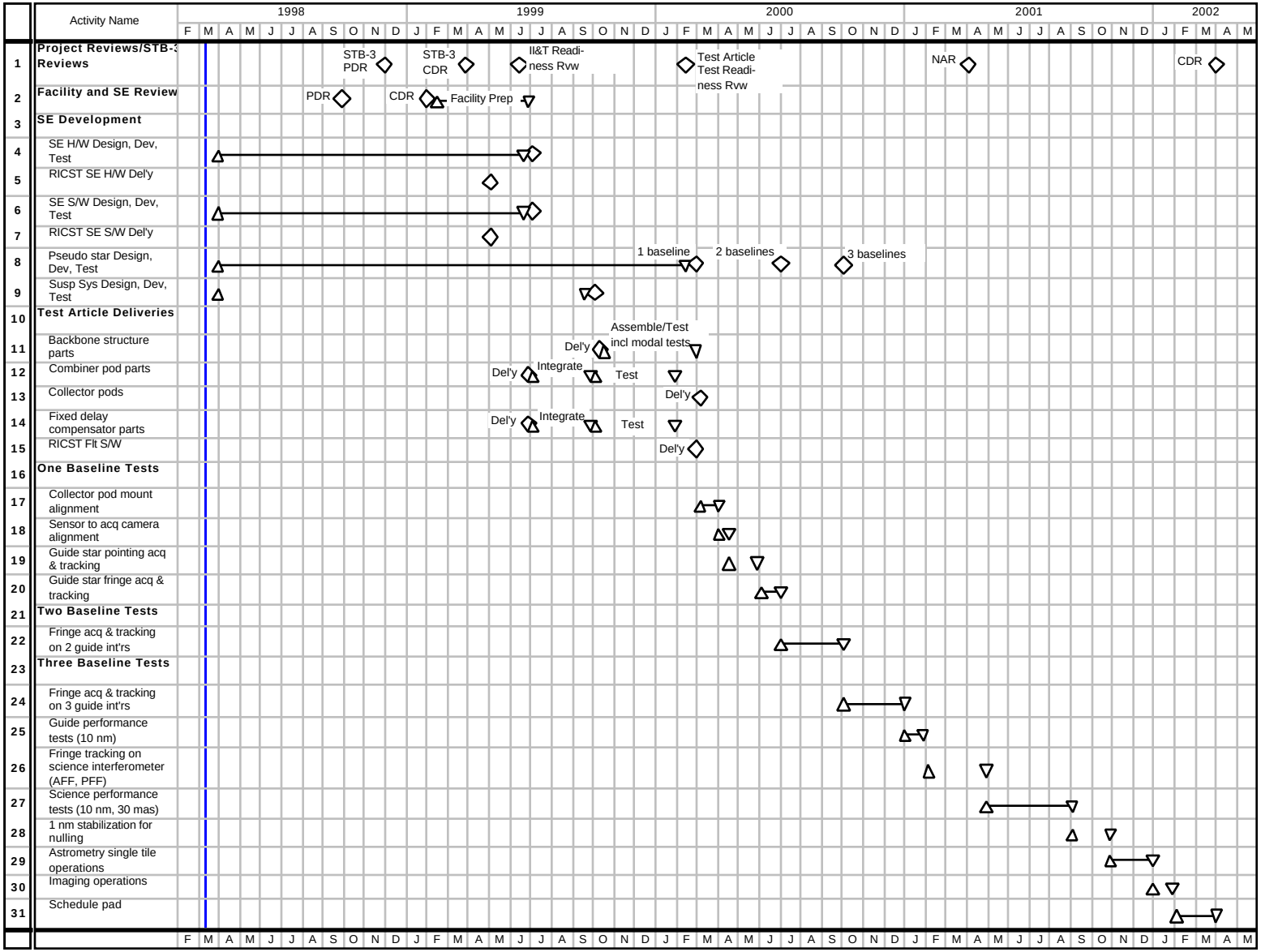
Pseudo Star Concept



LINEAR MOTION of COLLECTOR PODS TO CHANGE BASLINE LENGTH

1) Three beam combiners shown. One of 3 interferometers shown for clarity
2) 3 complete interferometers needed in the Pseudo Star

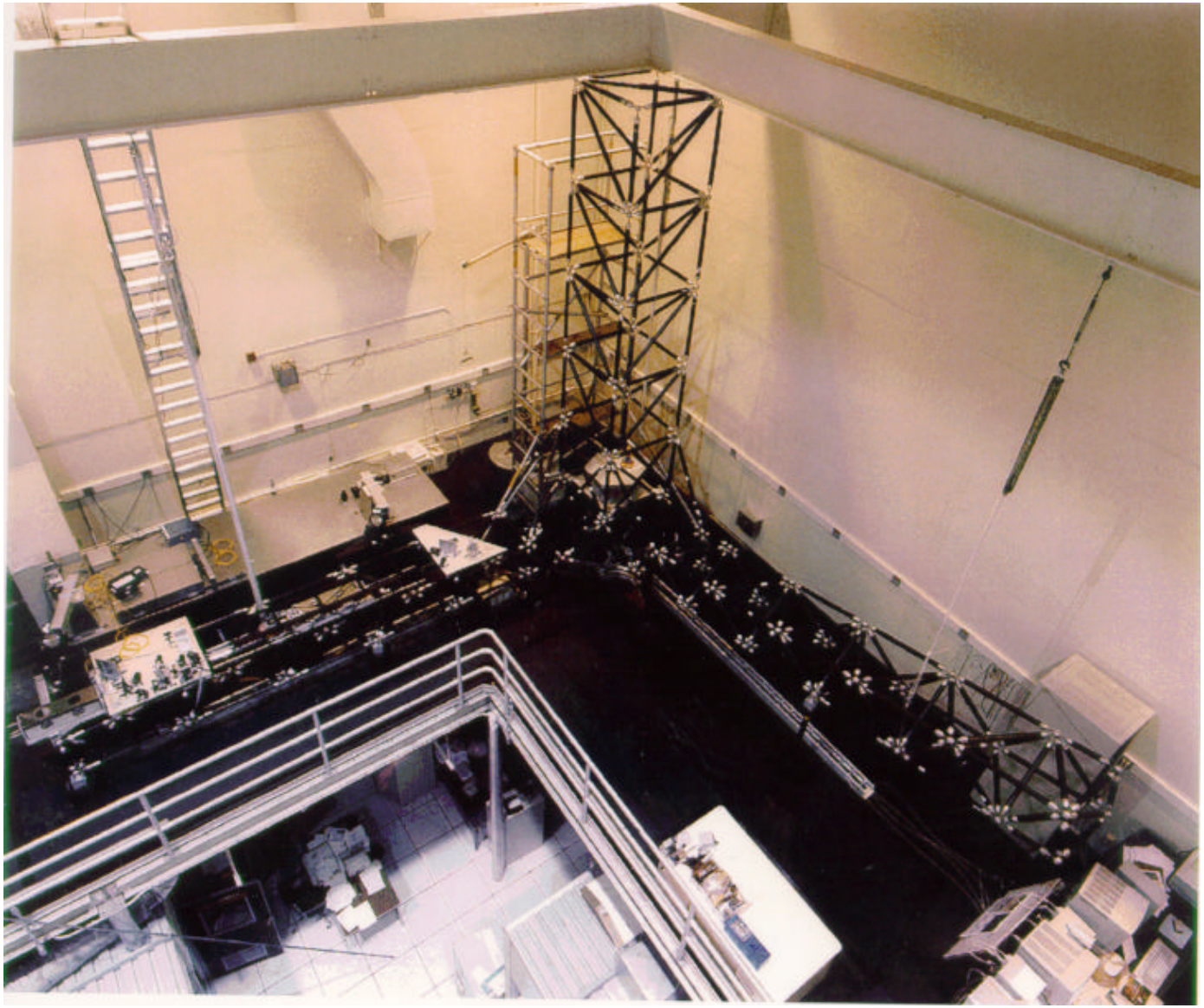
STB3 Schedule



STB-1 Objectives

- Technology Risk Reduction Objectives
  - Demonstrate System Level Vibration Attenuation
    - > Guide Interferometer Stabilization
    - > Science Interferometer Stabilization -- Angle Feedforward only
    - > Interferometer Stabilization for Nulling
  - Validate Integrated Modeling Methodology & Tools
- Programmatic Objective
  - Mitigates STB-3 Schedule Risk
- STB-1 Will Not:
  - Demonstrate full complexity operation using prototype software
  - Be a flight instrument integration and test “dress rehersal”
  - Operate throughout project life cycle supporting data handling and mission operations

STB-1 (aka MPI Testbed)



Summary / Concerns

- STB-3 Will Demonstrate Interferometer Full Complexity Operations and Nanometer Class Vibration Attenuation
  - Lab Ambient Requirements Will Be Challenging
    - > Likely to Prevent Testing to Absolute Performance Levels in Portion of Frequency Band
  - Emulated On-Orbit Vibration Attenuation Testing Valid Over Entire Frequency Band
- All Critical SIM Vibration Attenuation Technology Tests Will Ultimately Be Conducted on STB-3
  - Some Will Be Completed After NAR (as best we understand job today)
  - Schedule Compression Will Be Vigorously Pursued
    - > Need to Keep It Real
- STB-1 Mitigates STB-3 Schedule Risk
  - Will Accomplish Several Vibration Attenuation Technology Demos -- Less SIM-like Configuration
  - Many Lessons Will Be Learned for STB-3
- STB-3 Depends Heavily on RICST and Collector Pod Testbeds for High Quality and Timely Deliverables

Back-up Charts

Performance Assessment Procedure

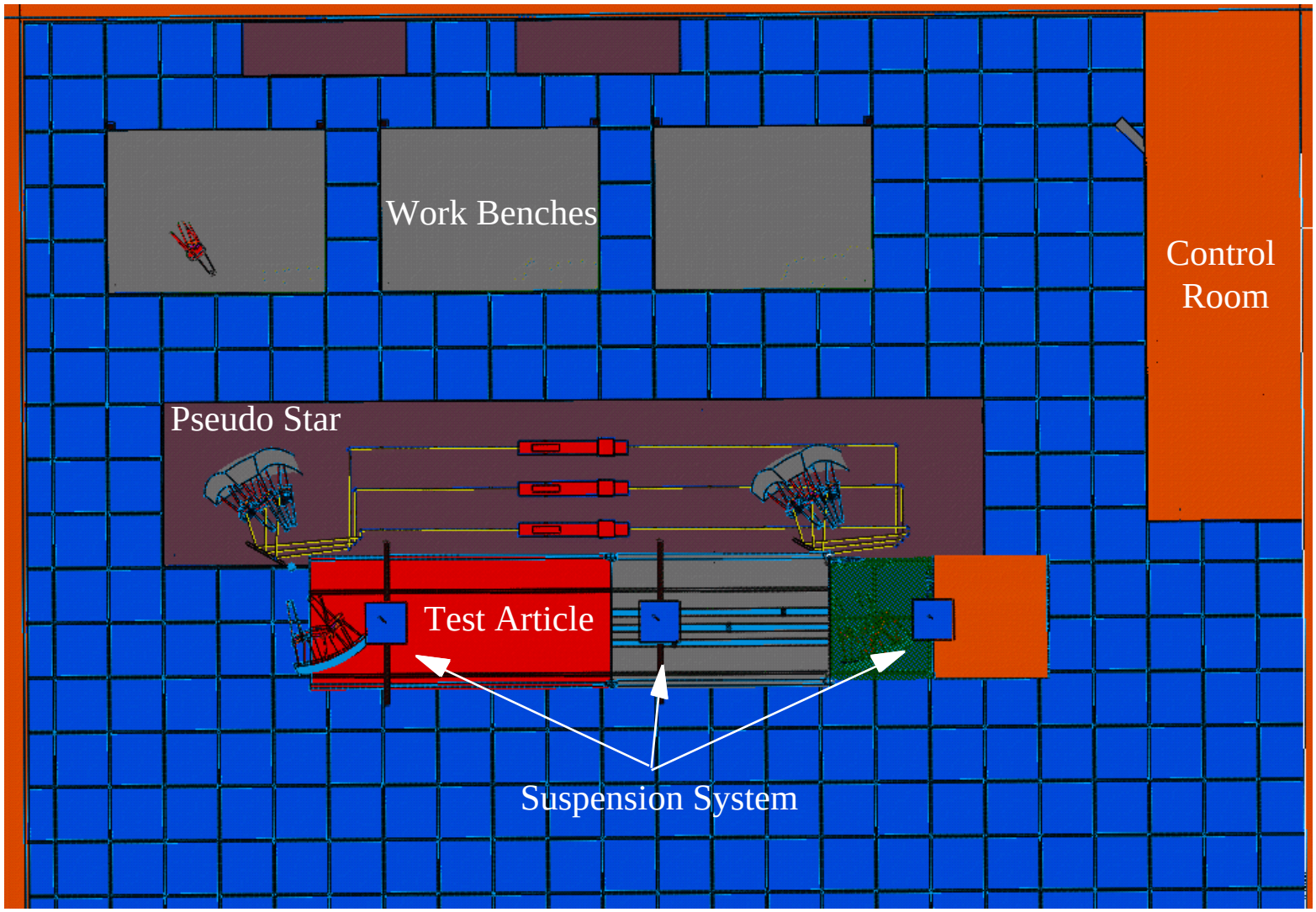
Disturbance Type	Lab Ambient - random seismic - random acoustic - random air flow	Emulated On-Orbit - sine swept shaker - above lab noise floor
Test Measurement	OPD & Angle Jitter on Detectors	Transfer Functions from Shaker to Detectors - lab ambient is averaged
Control Strategy	- Active Optics Only - Unconstrained Loop Bandwidths	- Active Optics + Isolation - Flight Traceable Loop Bandwidths
Results	Demonstrate System Can Operate at Required Absolute Precision	Demonstrate System Can Provide the Required Level of Vibration Attenuation

Bottom Line:
We Have Solved a Harder Problem in the Lab Than in Space

Summary -- STB-3 Performance Testing

- Emulated On-Orbit Testing Provides the Key Performance Metric
  - Valid across entire vibrational frequency spectrum
- Lab Ambient Testing Is Necessary to Demonstrate That Actuators, Sensors, and Controllers Function at the Required Resolution
  - Sufficient if demonstrated across limited frequency band
  - Problem frequency band: .01 Hz - 1 Hz (atmospheric effects)
  - This is a minor regret
- STB-3 Will Provide a Robust Test Environment to Accomplish Nanometer Class Vibration Attenuation Performance Testing

STB-3 Top View



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